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EXPERIMENTAL CALIBRATION AND IMPLICATIONS OF OLIVINE-MELT VANADIUM OXYBAROMETRY FOR HYDROUS MAGMAS FROM MUTNOVSKY VOLCANO (KAMCHATKA)

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A promising method for the quantification of the redox conditions (oxygen fugacity, fO_2) in basaltic systems, which might be applied to quenched melt inclusions in olivine, exploits the partitioning of vanadium between olivine and coexisting silicate melt (D_V^{Ol-M}). Strong correlation of D_V^{Ol-M} with fO_2 was investigated in a number of experimental works on dry mafic and ultramafic melts in a wide range of fO_2 conditions at pressures of 1 atm and 0.5–2 GPa, temperature range of 1150–1530°C (e.g., Canil&Fedortchouk, 2001; Mallmann&O'Neill, 2009; 2013). Only a few melt compositions equilibrated with olivine at T≤1250°C were studied so far. Although it was shown that melt composition, pressure and temperature have small effect on D_V^{Ol-M}, more data are required to extend the calibration of the V oxybarometry to hydrous low-temperature basalts representing island arc magmas.

This study presents new data on D_V^{Ol-M} gained from crystallization experiments performed with an high-Al basalt from Mutnovsky volcano (Kamchatka) at various aH_2O, 0.1 and 0.3 GPa, 1025-1150°C and ΔQFM= -0.5 to +3.2 at the Institute of Mineralogy in Leibniz University of Hannover. Concentrations of vanadium in experimental and natural glasses and olivines were analyzed at the Institute of Geosciences at the University of Kiel by LA-ICP-MS (Agilent 7500s, 193nm GEOLAS Pro). The determined D_V^{Ol-M} in run products varies between 0.007 and 0.079 and $\log D_V^{Ol-M}$ shows a strong linear correlation with logfO2 in the experiments.

For calibration of the V oxybarometer for low temperature hydrous basaltic magmas we used 7 experiments from this study together with 26 experiments performed at T≤1250°C in fO_2 range of -2.0 < ΔQFM < 3.2 with melts containing less than 12 wt% MgO and less than 4 wt.% Na_2O from previously published data. The resulting linear correlation between D_V^{Ol-M} and ΔQFM can be described with an equation: $\Delta QFM = -3.51 * \lg D_V^{Ol-M} - 4.20$ ($R^2 = 0.96$). This equation reproduces experimental ΔQFM conditions within ±0.35log units for 70% of the experiments.

This equation was applied to estimate redox conditions for Mutnovsky volcano magmas using compositions of melt inclusions in olivine from basaltic tephras. Vanadium concentrations vary in the range of 266–382 ppm in glassy inclusions and of 4.2–6.1 ppm in their host olivines. This corresponds to D_V^{Ol-M} = 0.0152–0.0185. The calculated ΔQFM values vary between +1.8 to +2.2 which is similar to the calculations using the equation from Canil and Fedortchouk, 2001 and is about 1 log unit of fO_2 below the value calculated with the oxybarometer proposed by Mallmann and O'Neill (2013). The determined redox conditions for Mutnovsky are in a good agreement with redox estimates using independent methods and confirm relatively oxidizing nature of island-arc basaltic magmatism.

References

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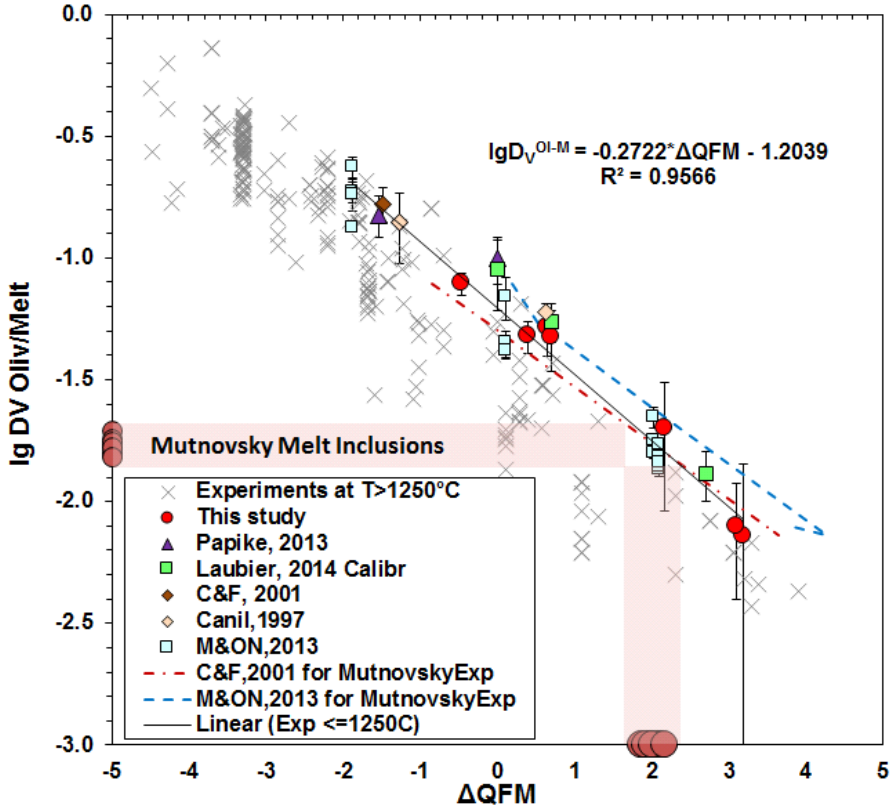
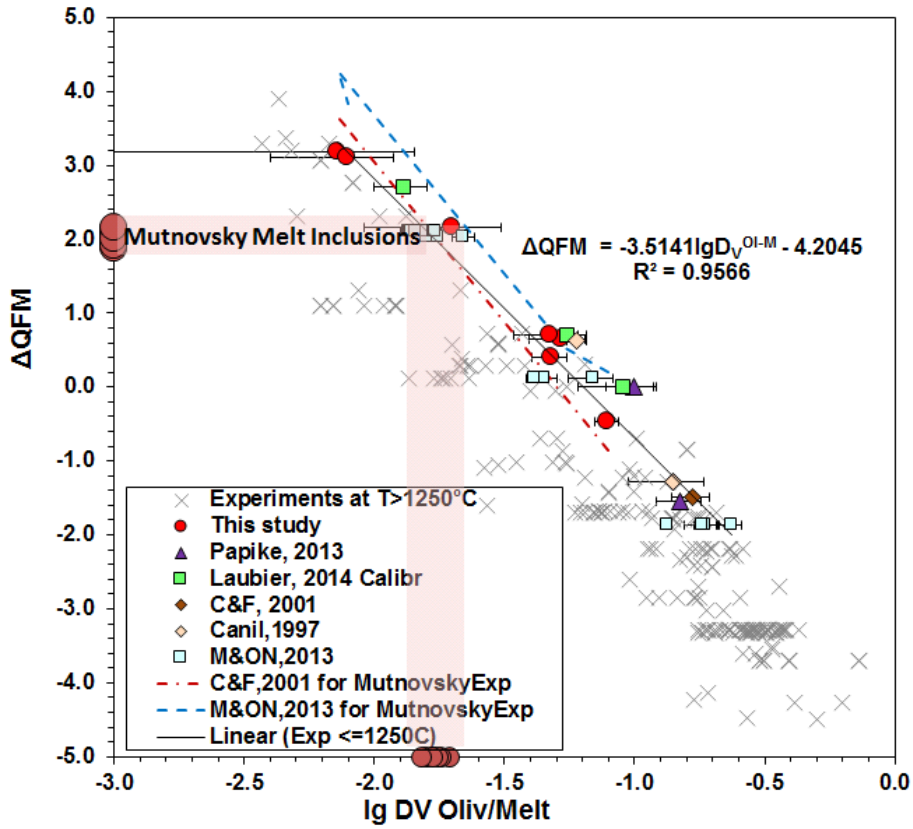

lgD$_V^{Ol-M}$ = -0.2722*ΔQFM - 1.2039
R² = 0.9566
Mutnovsky Melt Inclusions
Experiments at T>1250°C
This study
Papike, 2013
Laubier, 2014 Calibr
C&F, 2001
Canil,1997
M&ON,2013
C&F,2001 for MutnovskyExp
M&ON,2013 for MutnovskyExp
Linear (Exp <=1250C)
lg DV Oliv/Melt
ΔQFM


ΔQFM = -3.5141lgD$_V^{Ol-M}$ - 4.2045
R² = 0.9566
Mutnovsky Melt Inclusions
Experiments at T>1250°C
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Papike, 2013
Laubier, 2014 Calibr
C&F, 2001
Canil,1997
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ΔQFM
lg DV Oliv/Melt